The Great Eruption of 1912

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Within the broken edifice of a decapitated Mount Katmai is a lake 2 miles (3 km) wide.

On the afternoon of June 6, 1912, a volcanic eruption cloud rose 100,000 ft (32 km) into the sky above the Katmai region, 280 miles (450 km) southwest of Anchorage on the Alaska Peninsula *(Fig. 1)*. Explosions were even heard in Cordova, over 370 miles (600 km) away from the Alaska Peninsula. Winds pushed the ash cloud east and within a few hours, ash from a huge volcanic eruption began to fall on Kodiak Island, approximately 100 miles (170 km) southeast of the volcano. Within several hours ash fell on Vancouver, British Columbia and Seattle, Washington. The next day the ash cloud passed over Virginia, and by June 17th it reached the skies above Algeria in Africa *(Fierstein and Hildreth, 2001)*.

While those on board the steamship Dora in the Shelikof Strait, between Kodiak Island and the Alaska Peninsula, watched the towering eruption cloud, pulses of magma from beneath the volcano continued to reach the earth's surface. As the magma depressurized, gases quickly escaped, explosively hurling the molten rock skyward, where it chilled quickly to volcanic ash and pumice. The volume of pumice and ash rushing out of the vent was so great that not all of it became airborne. A flood of pumice spilled out of the choked vent and flowed as a pyroclastic flow—a dense, tumbling mixture of pumice blocks, fine ash, and hot gas—that moved down the former Ukak River valley to form the nearly flat topography seen in the Valley of Ten Thousand Smokes today *(Fig. 2) (Fierstein, 1984)*.

During the next three days, life on Kodiak Island was immobilized during the 60-hour eruption. Darkness and suffocating conditions caused by the falling ash and sulfur dioxide gas rendered villagers helpless *(Fig. 3)*. Among Kodiak's 500 inhabitants, sore eyes and respiratory problems were widespread. Water became undrinkable. Radio communications were disrupted and visibility was nil. Roofs in the village collapsed under the weight of more than a foot of ash. Buildings were destroyed as avalanches of ash rushed down from nearby hillsides *(Fierstein and Hildreth, 2001)*.

On June 9th Kodiak villagers saw the first clear, ash-free skies in three days, but their environment had changed fundamentally. Wildlife on Kodiak Island and in the Katmai region was decimated by ash and acid rain from the eruption. Bears and other large animals were blinded by thick ash and many starved to death because large numbers of plants and small animals were smothered in the eruption. Birds blinded and coated by volcanic ash fell to the ground. Even the region's prolific mosquitoes were exterminated. Aquatic organisms in the region perished in the ash-clogged waters. Salmon, in all stages of life, were destroyed by the eruption and its aftereffects. From 1915 to 1919, southwestern Alaska's salmon-fishing industry was devastated *(Fierstein, 1998)*. The biological impact was far worse overall than that of the Exxon Valdez oil spill in 1989 *(Fierstein and Hildreth, 2001)*.

The impact to the land did not cease when the eruption ended. A number of moderate sized lahars—volcanic debris flows consisting of rapidly flowing mixtures of water, mud, and rock debris—resulted from the 1912 eruption. The most publicized lahars occurred a few years after the eruption itself. A landslide, triggered by earthquakes during the 1912 eruption, dammed the Katmai River in Katmai Canyon. The Katmai River remained

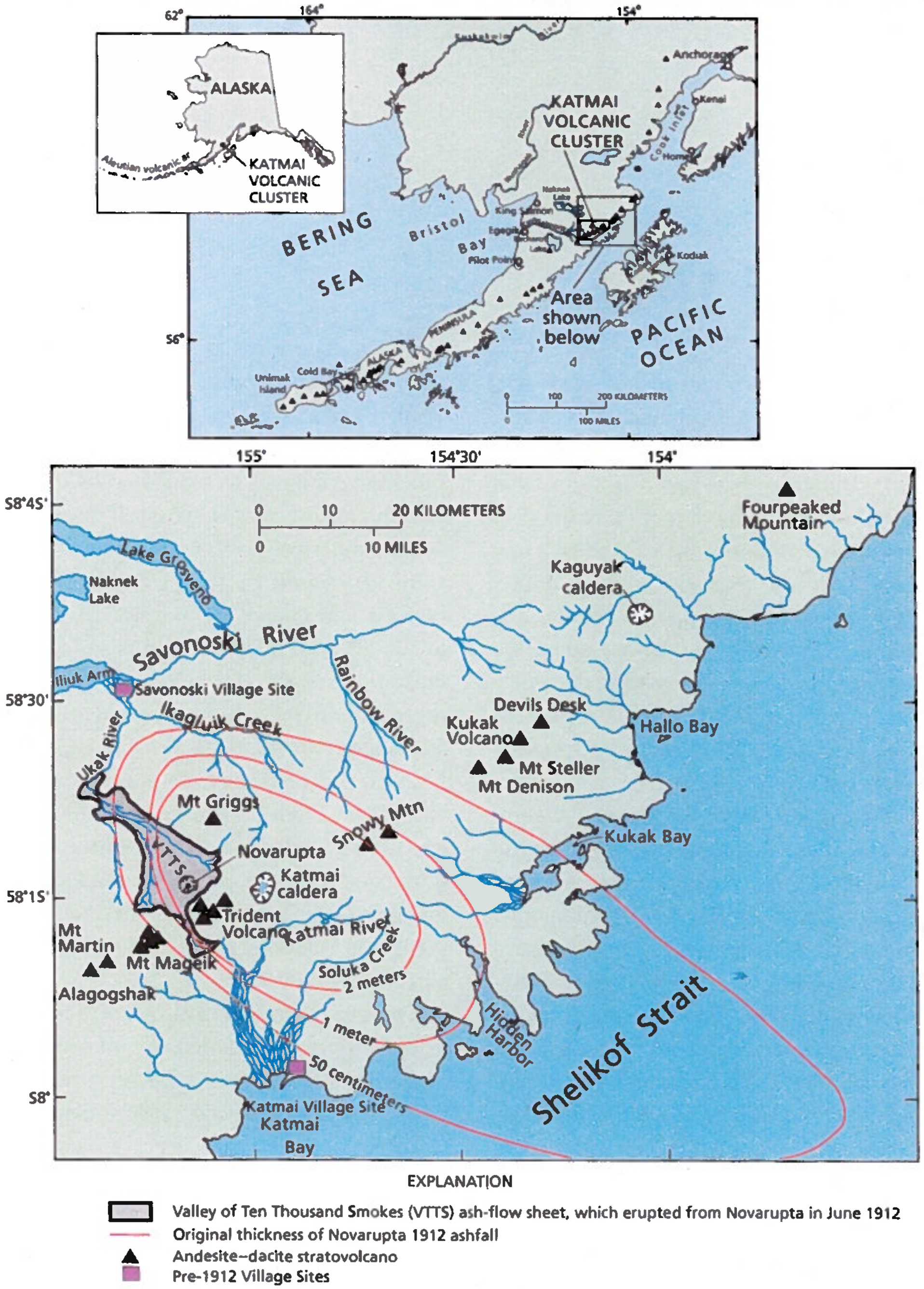

Figure 1. Regional geographic setting of the Katmai volcanic cluster with respect to other young volcanoes of the Aleutian arc. (modified from Fierstein and Hildreth, 2001)

dammed for three years until a very heavy snowmelt in 1915; the dam was breached and an enormous flood broke out into Katmai Canyon. Prior to his exploration of the Valley of Ten Thousand Smokes, botanist Dr. Robert F. Griggs landed on the shore of Katmai Bay in 1915—nearly 19 miles (30 km) downstream from Katmai Canyon. There he "found the countryside ravaged by a great flood whose waters were just subsiding." *(Griggs, 1922)*. Although Griggs called it a 'flood', a great volume of debris was also transported during this event. The tidal-flat area, 6 miles (10 km) wide, was choked with pumice and ash, turning upriver stretches of land into quicksand and destroying Katmai village (already abandoned in 1912). Trees were snapped off near ground level for several miles by the violent impact of the water, a fan of huge boulders was deposited at the mouth of the canyon, and the water volume was so great that it flooded the valley to a depth of approximately 10 feet (3 m) *(J. Fierstein, personal communication, 2002)*.

Katmai National Monument and the Discovery of a New Volcano

In 1916, the National Geographic Society funded an expedition to Katmai led by botanist Dr. Robert F. Griggs. This was the first group of scientific explorers to visit the Katmai region. Mount Katmai was believed to be the source of the material erupted over those three days in June 1912. Within the broken edifice of a decapitated Mount Katmai, Griggs and his party saw a lake 2 miles (3 km) wide of robin's egg blue water and a small dacite lava dome they named Horseshoe Island *(Griggs, 1922)*.

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Figure 2. The Valley of Ten Thousand Smokes at sunset, mountains in back are, left to right, Jule Peak and Griggs (formerly known as Knife Peak).

This island is now submerged beneath 820 feet (250 m) of lake water (Fig. 4) *(Fierstein and Hildreth, 2001)*. Only six miles (10 km) south of Mount Katmai, the party discovered another newly formed volcanic dome, a crumb cake of gray rock about 1,200 feet in diameter and 150 feet high, which they named Novarupta (Latin for new vent) *(Fig. 4) (Rozell, 2001)*. West of these two volcanic features lay voluminous flows of volcanic ash that filled the valley to as much as 650 feet (200 m) deep. Griggs named this area the "Valley of Ten Thousand Smokes" for the numerous jets of steam ascending from the hot volcanic material covering the valley floor *(Fig. 5) (Fierstein and Hildreth, 2001)*.

In 1918 Griggs' descriptions of these spectacular features helped persuade President Woodrow Wilson to designate Katmai National Monument, to preserve the dramatic landscape for future generations to experience and for scientific study *(Guffanti, 2001)*. In the 1930s Katmai National Monument was described as, "not only the largest, but also the most spectacular member of the monument system." *(Glimpses of Our National Monuments, 1930).*

Griggs and others believed that the Valley of Ten Thousand Smokes was a modern-day example of how the geyser basins of Yellowstone Park were formed as the region's volcanoes first ceased their activity *(Glimpses of Our National Monuments, 1930).* This turned out not to be the case. By the 1930s, the valley-filling ash had cooled enough to allow liquid water to pass freely through without it turning to steam *(Fig. 6).* Today, the Valley of Ten Thousand Smokes is largely smokeless. Warm vapors rise from a few places around the Novarupta vent and along the margins of Baked, Broken, and Falling Mountains as the groundwater percolating through underground fractures turns to steam as it approaches the still-hot rock beneath Novarupta. These few remaining fumaroles tap a deep heat source—molten rock below ground. This is quite different from the "rootless" heat source of the extinct fumaroles, which was actually the cooling of the ash-flow itself *(Fig. 6) (Fierstein, 1984).*

The origin of the magma expelled in the 1912 eruption has been a topic of great interest. In fact, in 1953 more than forty years after the eruption, Dr. Garniss Curtis of the University of California discovered that the main vent for the great eruption was not Mount Katmai, as previously thought, but a new vent, now plugged by the dome Griggs and his party named Novarupta *(Fig. 7).* Curtis postulated that so much molten rock was removed from beneath Mount Katmai that Katmai's summit collapsed to form a volcanic depression 2 miles (3 km) wide, called a caldera *(Fig. 4) (Fierstein and Hildreth, 2001).* Although in the 1950s Dr. Curtis discovered what happened during the 1912 eruption, researchers continue to attempt to understand how and why the magma from underneath Mt. Katmai erupted through the vent at Novarupta.

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Figure 3. Drifts of ash in the village of Kodiak, June 1912 by W.J. Erskine

Research, Exploration and Katmai National Park and Preserve

Volcanic particles suspended in the air—dust and sulfurous aerosols—from the 1912 eruption were detected within days over Wisconsin and Virginia and over California, Europe, and North America within two weeks *(Fierstein and Hildreth, 2001).* Beginning in 1913, before anyone had set foot in the Valley of Ten Thousand Smokes, the transport of the volcanic ash cloud, reported as a dust veil as far east as Greece and Algeria, led to pioneering work on atmospheric turbidity and the effect of aerosols on climate *(Kimball, 1913; Volz, 1975; Fierstein and Hildreth, 2001).*

Modern scientific study in the Valley of Ten Thousand Smokes began in the 1950s *(Norris, 1996)*, and nearly 30 years later

Figure 4.
Top: Mount Katmai by R.F. Griggs of the 1915 and 1916 expedition

Middle: Novarupta Steam

Bottom: Present day Katmai Lake

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Figure 5. Valley of Ten Thousand Smokes, photo by D. B. Church

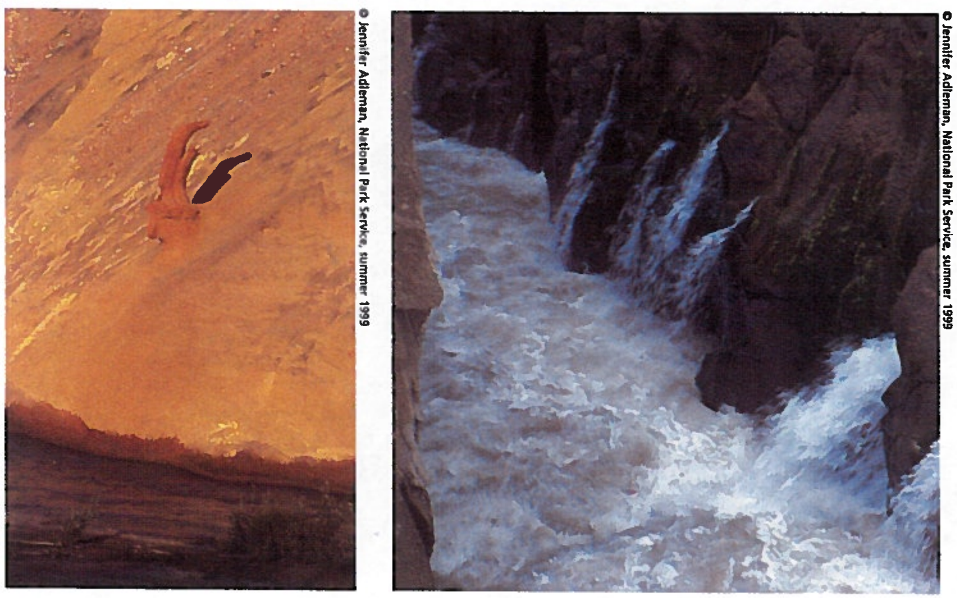

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Figure 6.
Left: Fossil fumarole along Windy Creek in the Valley of Ten Thousand Smokes.

Right: Ground water moving through welded tuff and into the River Lethe in the Valley of Ten Thousand Smokes.

Katmai National Park and Preserve was designated, encompassing the Valley of Ten Thousand Smokes and surrounding regions. Around that time, part of the ongoing U.S. Geological Survey (USGS) fieldwork culminated in surface and bedrock geologic maps of the region. The University of Alaska, Fairbanks Geophysical Institute (UAFGI), the USGS, and later the Alaska Volcano Observatory (AVO), and others, continue to unravel the mysteries of 1912.

The Katmai Cluster

Scientists now refer to the volcanoes surrounding the Valley of Ten Thousand Smokes as the Katmai Cluster, a 15 mile-long (25 km) line of volcanoes along the Alaska Peninsula *(Fig. 1)*. Recent work in the Katmai area has established an eruptive history for each of these volcanoes by mapping the distribution of erupted materials. Radiometric dating identifies minimum and maximum ages for the different lava flows. Combined with mapping, these radiometric dates help narrow down the timing and frequency of past eruptions. The Katmai Cluster includes (from northeast to southwest) Snowy Mountain, Mount Griggs, Mount Katmai, Trident Volcano, Novarupta volcano, Mount Mageik, Mount Martin, and Alagogshak volcano *(Fig. 8)*. All but Alagogshak have erupted within the last 6,000 years, often explosively, and produced lava flows, domes, and widespread ash deposits. No fewer than 15 eruptive episodes have originated from the Katmai cluster within the last 10,000 years *(Fierstein and Hildreth, 2001)*.

Recent studies of the 1912 eruption have allowed researchers to further investigate the processes and hazards associated with large explosive volcanic eruptions. Recently published estimates of total volcanic material erupted in 1912 at Katmai include 4 cubic miles (17 cubic km) of ash fall and 2.6 cubic miles (11 cubic km) of ash-flow deposit, with 3 cubic miles (13 cubic km) of liquid magma *(Fierstein and Hildreth, 2001)*.

The 1912 eruption of Novarupta was the twentieth century's most voluminous eruption, and one of the five largest in recorded history. Among historical eruptions it is one of the few to have generated a large volume of pumiceous pyroclastic flow that came to rest on land instead of in water. Over the last two decades, detailed studies of the Katmai region's eruptive deposits have contributed to a better understanding of how volcanoes work, including the concurrent production of tremendously high ash plumes and ground hugging ash flows,

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Figure 7. Today, the blocky lava dome of Novarupta sits in the ash-and-debris-filled volcanic crater, created by a cataclysmic volcanic eruption in 1912 that rained ash over southern Alaska, western Canada, and the Pacific Northwest (Fierstein, 1998).

The chance of a Novarupta-scale eruption occurring in any given year is small, but such cataclysmic volcanic events are certain to happen again in Alaska. In 1912, Alaska was sparsely populated and there were few airplanes. Now, over six hundred thousand people live in Alaska, and aircraft carrying more than 10,000 passengers and millions of dollars in cargo pass over Alaska's historically active volcanoes each day.

the timing of caldera collapse relative to magma withdrawal, and the distance pumice and ash may travel from the source *(Fierstein and Hildreth, 2001).*

Katmai Quakes

Generally, earthquake activity beneath a volcano increases before an eruption because magma and volcanic gas must first force their way up through shallow underground fractures and passageways. When magma and volcanic gases or fluids move, they may cause rocks to break or cracks to vibrate. When rocks break, high-frequency earthquakes are triggered; however, when cracks vibrate either low-frequency earthquakes or a continuous shaking called volcanic tremor is triggered *(Tilling, 1997).* Fourteen earthquakes of magnitude 6 to 7 rocked the region, and countless smaller shocks occurred before, during and after the 1912 eruption of Novarupta *(Fierstein, 1998).*

The volcanological significance of earthquakes in Katmai National Park has been debated since the first seismograph was installed in 1963. Katmai seismicity consists almost entirely of earthquakes that can be caused by regional or local tectonic forces. Some of the earthquakes appear to result from rock failure under loading conditions along with local increases in the number of earthquakes associated with hydrothermal fluids. Earthquakes occur along fractures formed near the Mount Trident and Novarupta area during the 1912 eruption. These fractures may now serve as horizontal paths for migrating fluids and/or gases from nearby cooling magma bodies. At Mount Katmai, earthquakes may also occur along the ring-fracture systems created during collapse of the mountains summit in 1912. Circulating hydrothermal fluids and/or seepage from the caldera-filling lake may contribute to the occurrence of these earthquakes *(Moran, in press).*

Magma(s?) of Katmai

Studies have proposed conflicting models for the magmatic plumbing system that fed the mechanism that triggered the eruption at Novarupta and collapse of Mount Katmai. One model of the eruption requires a single, chemically zoned, magma chamber beneath Mount Katmai *(Hildreth and Fierstein, 2000).* Another model requires that the large pocket of molten rock that supported the former summit of Mount Katmai was injected with magma from another source and triggered the eruption of 1912 *(Eichelberger, 2000).* This model requires that the magma under Katmai traveled six miles (10 km) west through an underground channel to explode through the surface at Novarupta *(Eichelberger, 2000).* An experimental investigation,

Figure 8.
Some volcanoes of the Katmai Cluster.

Top: Alagogshak volcano

Middle: Four peaks in the background are Trident Volcano, and the dome in the center is Novarupta.

Right: Mount Griggs

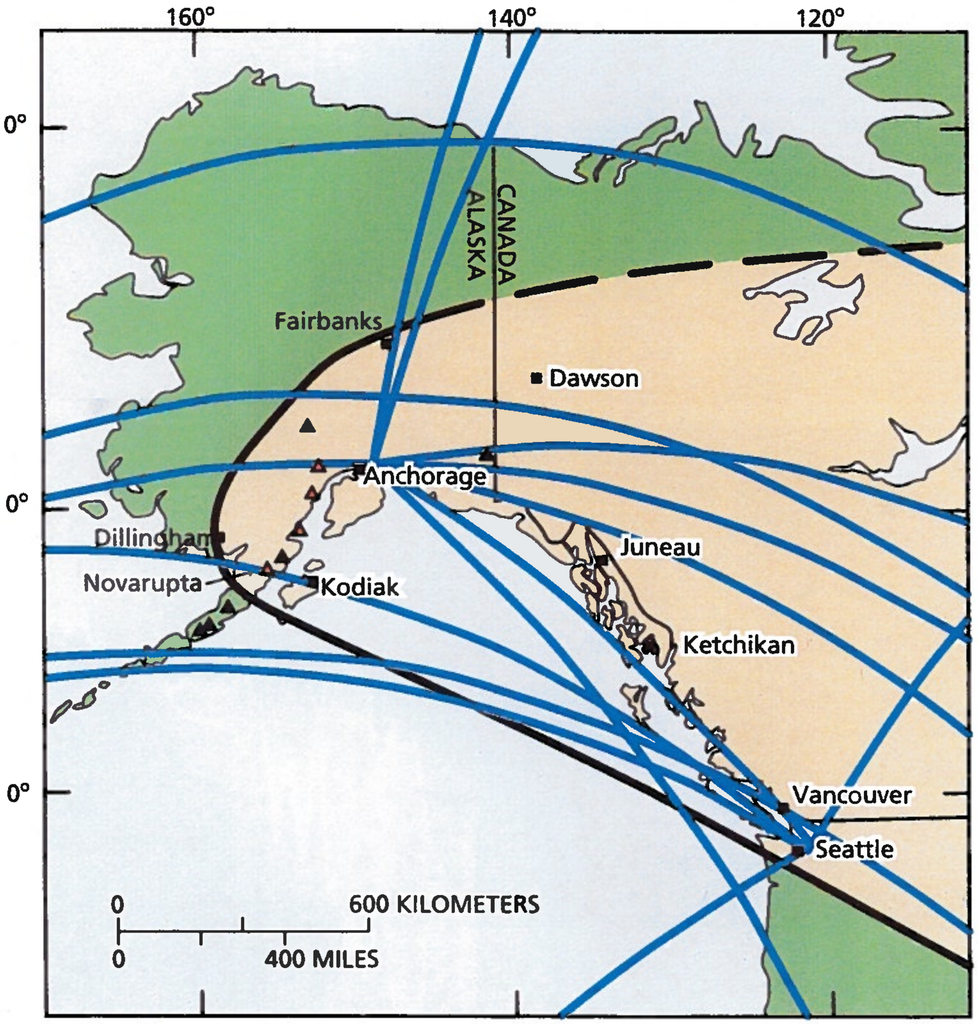

Figure 9. Great-circle and other air-traffic routes (blue lines) between selected cities (Casadevall et. al., 1999) would have been disturbed greatly by the 1912 ashfall from Novarupta. (Fierstein and Hildreth, 2001).

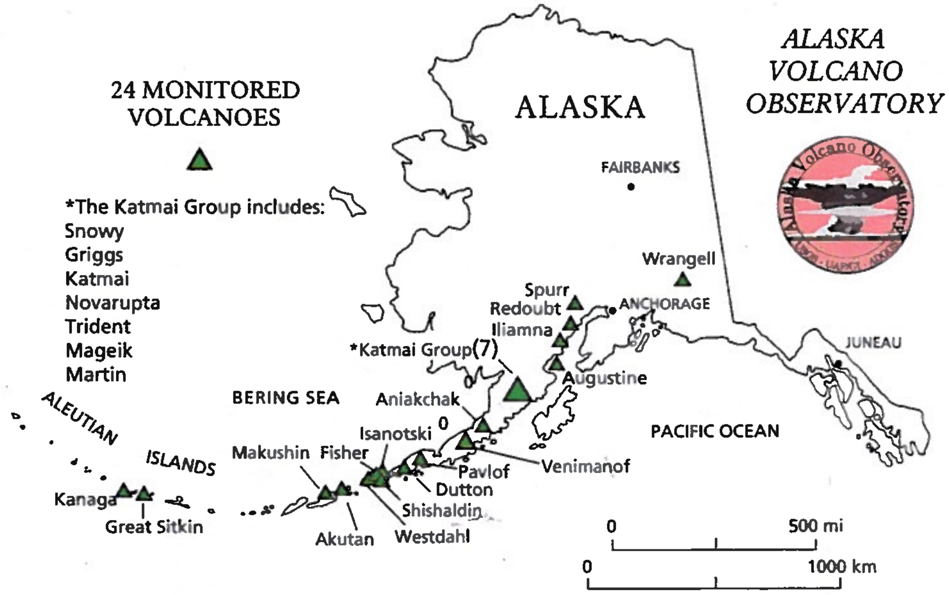

Figure 10. Volcanoes monitored by the Alaska Volcano Observatory as of summer 2002.

performed in a laboratory, concluded that the Katmai magma in the upper crust prior to eruption must have been 1,470°-1,560° F (800°-850° C) in temperature. The same laboratory studies also suggest that the pre-eruptive storage and crystal growth of the erupted magma was at a shallow depth, or if the magma ascended from greater depth, it did so slowly *(Coombs, 2001)*. Many scientists deviate on almost every aspect of the type of plumbing system and mechanisms that triggered the eruption at Novarupta and the subsequent collapse of Mount Katmai. To complicate matters, Fierstein and Hildreth (2000) determined that the Katmai summit collapse compensates for only 40% of the magma erupted in 1912. Studies in the Valley of Ten Thousand Smokes continue to look for evidence of the plumbing system and triggering mechanisms at the Valley of Ten Thousand Smokes.

Alaska's Active Volcanoes: Katmai and Beyond

The chance of a Novarupta-scale eruption occurring in any given year is small, but such cataclysmic volcanic events are certain to happen again in Alaska. In 1912, Alaska was sparsely populated and there were few airplanes. Now, over six hundred thousand people live in Alaska, and aircraft carrying more than 10,000 passengers and millions of dollars in cargo pass over Alaska's historically active volcanoes each day. The greatest hazard posed by eruptions of most Alaskan volcanoes today is airborne ash — even minor amounts of ash can cause the engines of jet aircraft to fail during flight *(Fig. 9) (Fierstein, 1998)*.

Today, the heavy ash fall produced by a Novarupta-sized eruption in southern Alaska would bring the state's economy to a standstill, create health problems, close roads and airports, disrupt utilities, and contaminate water supplies for hundreds of miles. Promptly restoring normal life would depend heavily on community spirit, civic organization, and pre-eruption planning *(Fierstein, 1998)*.

Throughout the western United States an increased focus on volcanic disasters began after the 1980 eruption of Mount St. Helens in Washington State. However, it was the 1986 eruption of Alaska's

Augustine Volcano 180 miles (290 km) southwest of Anchorage that prompted the formation of the Alaska Volcano Observatory and an increase in volcanic monitoring along the Alaska Peninsula, the Aleutian Islands and throughout the North Pacific. The Alaska Volcano Observatory (AVO) is a joint program of the USGS, the Geophysical Institute of the University of Alaska Fairbanks, and the State of Alaska Division of Geological and Geophysical Surveys. AVO uses federal, state, and university resources to monitor and study Alaska's hazardous volcanoes, to predict and record eruptive activity, and to mitigate volcanic hazards to life and property *(Fig. 10)*.

Now, nearly a century since the eruption that formed the Valley of Ten Thousand Smokes, a sizeable amount of monitoring and research instruments have been deployed throughout the state. Today, Katmai's well-established seismic network and benchmark stations are now augmented with satellite imagery, periodic field-based Global Positioning System (GPS) surveys, and gas, geochemical and hydrologic studies. Researchers continue to focus on understanding how volcanoes work, and on monitoring Alaska's active volcanoes and mitigating risks associated with volcanic activity.

More information can be found on the USGS website **www.usgs.gov** or the National Park Service website **www.nps.gov/katm.**

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